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Development of a practical computer network course through Netkit virtualization tool

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Abstract

Virtualization tools have been used in computer network classes to provide a environment for practice experiments. Although some papers describe these tools and their technical benefits, they do not provide quantitative information about its effectiveness. This paper presents a proposal for systematic use of this category of tools in computer classes and a evaluation of use Netkit tool in computer network classes. It will be shown how tutorial sections has been developed to these courses, the receptivity from the students through surveys and a statistical analysis of how much students grades can be improved by applying such tutorials. Finally, it will be possible to conclude that, in fact, the use of such tools is strongly advised.

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1. Introduction

Virtual computer networks are wide-spreading along researchers, administrators and teachers all around the world. These kinds of tools provide a solution for creating low-cost experiments that any student can run in their personal computer, even if it has a modest configuration [1]. In the context of distance learning, where a student does not have, essentially, access to an adequately equipped computer network laboratory, these tools

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are indeed valuable. Although some educational institutions are already using it in their computer network classes [2], there is no consolidated practice about the use of these tools and, currently, only a few studies [12] describes how much effective these tools when applied in the context of teaching and learning process.

From the educational perspective, from researchers and academic perspective to industry expectations, the professional formed by industry needs to be prepared to handle a large number of issues [3]. In computer network domain, this means that the recently graduated professional will need to perform configuration of servers, security hardening of networks, routers configurations, among other tasks. Simulators like *Cisco Packet Tracer* [10] enable some level of experimentation. However, such simulators have a strong limitation. Students are unable to install free and wide spread software used by network administrators.

In this paper we discuss the use of *Netkit* tool in computer network practical courses. It will be discussed also, how educational modules were developed using IMA-CID (*Integrated Modeling Approach - Conceptual, Instructional and Didactic*) [14]. From the conceptual model developed using IMA-CID, it was developed tutorials that covered the course program, together with theoretical lessons, which could be streamed over Internet in distance learning courses or taught in traditional manner in classroom courses. Finally, it will be presented an effectiveness evaluation realized at ICMC / USP (Institute of Mathematics and Computers Sciences, University of São Paulo), demonstrating how *Netkit* could improve the student's apprenticeship.

The next sections of this paper are organized in the following manner: The section two presents some related works that explores simulators and virtualization in computer sciences courses. The section three presents IMA-CID and how computer network topics were modeled. The section four describes how *Netkit* topics were translated into tutorials and how they were used in the classes. A performance evaluation of the course using *Netkit* will be present at section five. The last section presents the conclusions.

2. Related works

It is important to note that the authors of this paper are not the creators of the tool *Netkit*. The authorship attributed to them are the tutorials and the formal evaluation of the effectiveness of using this teaching method and tools, corroborating results demonstrated in other areas of knowledge to teaching and learning computer networking process. Some studies are referred, although they were applied to other areas of knowledge, helped in the development of tutorials and evaluations performed in this paper.

Gadelha et al. (2010), presents the OS Simulator, which consists of a simulator file system to support the teaching and learning of operating systems. The authors' work demonstrates a tool created and the positive feedback obtained through questionnaires to students [4]. Fuertes and Vergara [Fuertes and Vergara 2007] present the VNUML, a virtualization tool similar to *Netkit* virtualization of networks, with very similar features and also based on UML. The article shows a comparison of performance between the VNUML, *Netkit* and other similar tools[1]. **RCOS.Java** simulator is an open source operating system presented in Jones and Newman (1996) [7]. The paper demonstrates the authors' motivation for creating the tool, although it has not, the time the article was evaluated for detection of ongoing learning level. This work has contributed significantly to the educational foundations explored in the tutorials developed for teaching computer networks. Dobrilović et al. (2012), presents a study evaluating the use of VNLab tool, its usability and curricula coverage. VNLab is a permanently virtual network hosted at Technical Faculty "Mihajlo Pupin", University of Novi Sad, Serbia. The students are able to connect to the virtual laboratory using a remote access tool and make experimentations. [15]

These studies show that it is relevant to the process of teaching and learning using computational tools to support, in particular simulators. Fuertes's article, in particular, compares various tools that could have been chosen to achieve the same goal. It is very important to point out that there are several simulators of computer networks, however, none is used with a view to improving the quality of teaching and learning level of the students, especially the way it is presented in this article.

3. IMA-CID

Educational modules are concise units of study, composed by theoretical, composed by books, papers, websites and multimedia resources, and practical content, like program code, documentation and for the matter of this paper, virtual laboratory files. These contents are integrated in term of learning materials and needs a infrastructure to be correctly deployed to students. For systematically develop educational modules, Barbosa et al. (2004) defines some supporting mechanisms for their development. A Standard Process for Educational Modules and an integrated modeling approach for educational content (IMA-CID – Integrated Modeling Approach: Conceptual, Instructional and Didactic) were established [9]. This process works with three models. The first one, the conceptual, is a description of the domain being researched. A instruction model can be used to design additional information, like examples, presentations, multimedia content and other resources that can facilitate the learning process. Finally, the didactic model gives a sequence of the elements generated or used in prior models. IMA-CID considers aspects like audience, goals, length and resources available.

4. Netkit as a tool to support teaching and learning

Netkit is an emulator that enables the creation of experiments in virtual computer networks, including hardware devices needed for their support, as well as the creation of virtual links that interconnects these devices. The Netkit started to be developed as an open source, in 1999, in Rome Tre University, Italy, later receiving support from the scientific community [2]. The virtual machines provided by Netkit are initialized that, once running, provides practical experience to students, even if it has only one computer in your home. A Netkit virtual machine is a full Debian GNU / Linux. Appropriate software enables these virtual machines to act as any special network device such routers or switches[3]. To carry out the practical experimentation at computer network disciplines in ICMC / USP, 11 virtual laboratories were developed.

5. Apprenticeship evaluation

To evaluate the apprenticeship effectiveness of Netkit and practical tutorials implementation on learning, it was held two evaluations. There was considered a quantitative and a qualitative approach. For the quantitative approach, a particular difficult was to find some similar evaluation, even on another computer science discipline, in benefits of qualitative evaluations. For this reason, techniques of statistic performance evaluation like applied in information systems and softwares were done [10].

5.1. *Quantitative approach*

For the qualitative approach it was considered a case study where a comparison between two classes of discipline SSC-0152 (Network Administration and Management) held at ICMC / USP, equivalent prerequisites and the same professor. Each learning topic received a penalty, varying from 0, 0.7, 0.85 and 1, when it was not been sufficiently addressed. This penalty weight, called “Depth Level”, multiplies each subject average grade. From data collected it was possible to conclude that Netkit class got 3.31 in 10 points above the class that did not had practical lessons using Netkit. It was used a second metric called “level of knowledge”, a rank of 4 levels from unknown (1) to advanced (4). The class with practical Netkit lesson scored level 3, with a weighted average of 7.04 against a weighted average of 4.40 that ranked level 2. It is important to reinforce that 1) both classes had similar prior knowledge of the curriculum evaluated by a written test at start of respective terms, 2) these averages are not individual grades but data collected from tests and 3) although some subjectivism could be applied when choosing each Depth Level, very specified boundaries were established to avoid mistakes.

5.2. Qualitative approach

Apart from quantitative research, qualitative research was conducted through a survey conducted with students in two practical activities. These surveys, anonymously answered, were passed to get direct feedback from students' expectations. The students were asked to give a grade for each of 6 questions, from 0 to 5, with 5 as the highest rank. This is not a comparison evaluation, but some feedback systematically obtained from students to evaluate their satisfaction with the practices. The questions and averages received from 32 students showed they are happy and confident with the practical approach taken in the course.

6. Conclusion

This article discussed a evaluation of apprenticeship in computer networks through Netkit virtualization tool, and what strategies can be used to improve learning, proposing a working method that can be used in the classroom, or even in the homes of students in disciplines of education distance. It should be noted that the main contribution of this paper is to demonstrate the effectiveness of using the tool as a means of improving the process of teaching and learning in the disciplines of computer networks. Meanwhile, there was the development of study material following the models described here are available at website “www.paulogurgel.com.br”, this is the first study material using Netkit available in Portuguese, for the full course of networks. It is possible to completely observe the benefits of network virtualization in education, and in particular the use of Netkit tool in expanding the depth of content taught and the effectiveness of practical learning facilitated by the tool.

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